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1989-90 PROJECT SUMMARIES

THE UNIVERSITY OF TEXAS, AUSTIN
DEPARTMENT OF AEROSPACE ENGINEERING AND ENGINEERING MECHANICS

There were two NASA/USRA-sponsored Advanced Design efforts at UT Austin during the 1989-90 academic year, both associated with space design. The aerospace engineering program is a sustaining program and the mechanical engineering program is a new effort. Interactions between the two programs are strong, with faculty from each department acting as consultants to students from the other department. Both programs are now coordinating their activities through the new Texas Space Grant Consortium, a consortium of universities across the state of Texas. The aerospace engineering space design program is now coordinating with the department's aircraft design course, and abstracts of the spring aircraft design projects are included in this document. Undergraduates in the spring undergraduate design courses used subsystem design notes developed by graduate students in a fall 1989 graduate spacecraft design course. The aerospace engineering program has expanded its outreach considerably, publishing a newsletter, involving Dr. Harlan Smith of the UT Department of Astronomy in a fall design, bringing in a high-school intern to work with an undergraduate design team, using an undergraduate student from the humanities as a member of a fall design team, and having a student from ENSAE (Sup'Aero) in France work as a member of a spring design team. A new aerospace engineering graduate level design course was taught in fall 1989 in which preliminary designs for five different spacecraft were developed. Student designs summarized here include two undergraduate space designs and five graduate space designs from fall 1989 plus four undergraduate space designs and four undergraduate aircraft designs from spring 1990.

GEOSTATIONARY SATELLITE SERVICING FACILITY
UNDERGRADUATE, FALL 1989

The objective of this study is to create a preliminary design for a man-tendable orbiting servicing and repair facility for geostationary satellites. The facility is composed of two major elements: a habitation module and the satellite service bay. Satellite Retrieval Vehicles (SRVs) will be based at the facility and will rendezvous with satellites needing retrieval and repair. These satellites will be returned to the facility where their problems will be diagnosed telerobotically and then they will be stored. When several satellites have been retrieved and their problems analyzed telerobotically, a manned servicing vehicle will be sent, carrying the required parts, to effect the needed repairs. The repair crew will return to the Earth and the satellites will be returned to operational orbits.

The design features a nonpressurized service bay of octagonal cross-section connected to a pressurized cylindrical habitation module. The facility is powered by solar arrays on both sides of the station, mounted on long booms that also provide support for radiators. The design features a manipulator arm that is used in the repair and storage of satellites. Satellites awaiting repair can be stored outside the service bay.

LUNAR FARSIDE OBSERVATORY AND SCIENCE BASE
UNDERGRADUATE, FALL 1989

The objective of this study is to establish requirements for an observatory and science base on the farside of the Moon. A lunar observatory will allow highly accurate astronomical observations free from radio and atmospheric interference from the Earth. Such a facility will also serve as a base from which to conduct other scientific studies, thus allowing a nearside base to be designed for dedicated propellant production. The lunar observatory is designed as a man-tendable facility that can be assembled using autonomous and teleoperated robotics.

The design features an Arecibo-type antenna array for radio astronomy, a VLF array, optical telescopes, a solar observation package, and selenographic experimentation package. The base includes a nuclear power plant and habitation modules for a crew of four. The base was designed to operate for a year in the untended mode. Crew visits would last 90 days once per year.

TEXAS EDUCATIONAL SATELLITE
GRADUATE, FALL 1989

The goal of this study is to design a communication satellite, the Lone Star Satellite, to link universities, industry, research facilities, and high schools throughout the state of Texas. The services provided by this satellite could be expanded to include other southwestern states such as Louisiana, Oklahoma, and New Mexico to allow for cost sharing. Such a satellite would greatly enhance higher education by allowing universities and research centers to share lectures and seminars remotely via television. It would also provide an educational outreach program by allowing universities to broadcast lectures and programs to high schools. Communications capacity not used by the state and its agencies might be leased to the private sector to reduce the overall cost of the satellite. The primary requirement for the Lone Star Satellite (LSS) is to provide 24-channel capacity dedicated to TV signals only. An optional capability includes a steerable antenna to provide coverage of areas outside the main footprint. Another optional

capability is the inclusion of voice telecommunication channels for use by state agencies both from fixed bases and from mobile units.

The design features a three-axis stabilized, solar powered satellite similar to the commercial communications satellites currently in geostationary orbit. The satellite, on orbit, has a mass of about 680 kg. The satellite is powered by solar panels and is launched on a Delta-class booster.

ASTEROID RENDEZVOUS VEHICLE
GRADUATE, FALL 1989

The primary objectives of the proposed Multiple Asteroid Rendezvous Tracker and Explorer (MARTE) are to analyze the composition and characterize the motion of five asteroids. To achieve these objectives, the spacecraft will be composed of two major components: a laboratory lander craft and five minispacecraft. The laboratory lander will be equipped with a complete sample analysis laboratory along with multiple external sensors. Each of the five minispacecraft will be much smaller than the main lab and contain only a few instruments. The minispacecraft will be targeted to five separate asteroids where they will land and perform a preliminary surface analysis. The laboratory lander will then proceed to and land upon the asteroid deemed to be the most interesting as a result of the minispacecraft's findings, where it will perform a much more detailed analysis, including sampling.

There were a number of design issues that required study in the design of MARTE. First, the asteroids in the asteroid belt are in dissimilar orbits with widely ranging orbital elements. For this analysis, an arbitrary group of about 30 asteroids with semimajor axes less than 3 A.U. and inclinations of less than 1° was chosen. Five asteroids were chosen from these 30 as a target group based solely on their relative positions during the three-year period between 1998 and 2000. Since the shape and rotation rates of most asteroids are unknown, cameras will be placed onboard the minispacecraft to provide visual identification of the shapes and to determine the rotation rates from pictures taken during the approach. Another design issue is the need for a semiautonomous control for these spacecraft. Since the roundtrip time delay for signals between the spacecraft and Earth can be over 20 minutes, control of the spacecraft from Earth would be impractical. The use of multiple minispacecraft was a major design decision. Since obtaining data on a number of asteroids is the primary objective of MARTE, and since transfer of a single spacecraft between asteroids would require large velocity changes, a single spacecraft that performs rendezvous with multiple asteroids was found to be impractical. Thus, the multiple minispacecraft scenario was adopted.

TITAN PROBE
GRADUATE, FALL 1989

The objective of this study is to design a probe to study Titan, Saturn's largest moon. Titan possesses a significant atmosphere that is composed primarily of diatomic nitrogen; the surface pressure on Titan is 1.6 times that of Earth. Titan's atmosphere is compositionally similar to Earth's early atmosphere—primarily nitrogen with traces of organic chemicals, some of which are thought to have played a significant role in the development of life on Earth. The mission objective is to gather information about Titan's meteorology, geology, and history. The spacecraft chosen for this mission consists of two portions: an orbiter and a lander. The orbiter is based on the Mariner Mark II design that will be used for the CRAF and Cassini missions. Because a design exists for the orbiter, most of our effort is directed toward developing the lander. The main constraints for this mission will be similar to previous planetary missions: total weight and trajectory limitations. Additional constraints will be imposed on the lander due to atmospheric reentry and Titan's extreme surface conditions. The Mark II probe is a modular design and our design for the lander is modular, with all subsystems broken into functional packages. This allows for the inevitable budget cuts and mission redefinition. Major subsystems present on the Titan probe include power, propulsion, thermal management, aerodynamic deceleration, landing (both soft landing and penetrators), sensors, guidance and control, attitude control, and structure. The design relies heavily on past JPL successes, but is flexible enough to incorporate current and near-future technology.

SUBSYSTEMS COMMONALITY ASSESSMENT FOR LUNAR/MARS LANDERS
GRADUATE, FALL 1989

The focus of this project is to identify commonality in components of four different extraterrestrial lander vehicles that are likely to be used in the lunar/Mars program and to incorporate this information in common subsystem designs. The vehicles are the lunar piloted lander (LPL), the lunar cargo lander (LCL), Mars piloted lander (MPL), and Mars cargo lander (MCL). The LPL and MPL are both expected to carry four crewmembers from orbit to the surface and back. The MPL, however, will be expected to be a base of operations for several days on the first several missions to the martian surface. The LCL and MCL are similar in cargo capacity but differ in that the MCL is not expected to return to orbit.

The majority of the effort in this design project is directed toward the spacecraft subsystems since it is not expected that a single vehicle design will adequately handle all four missions. The subsystems examined are structures; propulsion; ECLSS; sensors; guidance, navigation, and control; computers; power; and thermal control. Commonality of subsystem design between the lunar/Mars program lander vehicles and the Earth-Mars crew transfer vehicle, which is the subject of a parallel study, are also examined. Cost savings in both the design and operations phases of a program can be achieved by setting commonality and maintainability goals early in a vehicle development program. In this study each lander vehicle's subsystem requirements and physical parameters are researched in detail and conceptual designs for the four landers are presented. Key enabling technologies are identified. By examining the four lander vehicles as a family of spacecraft constructed from common components, it is hoped that design considerations that affect program costs have been identified.

NUCLEAR THERMAL ROCKET-PROPELLED EARTH-MARS VEHICLE GRADUATE, FALL 1989

The goal of this study is to present a design for a cargo- and/or crew-carrying Mars vehicle, the Mars Transfer Vehicle (MTV). This study deals mainly with hardware and systems integration rather than mission planning or trajectory analysis. Design features are (1) functional commonality; (2) propulsion system performance, reliability, and potential for further development; (3) crew safety; and (4) ease of construction. Functional commonality is important so that the vehicle can serve multiple purposes. The propulsion system chosen, a major driver in the design, will probably have far-reaching effects, since later vehicles may use derivatives of this system. Systems to protect the crew significantly affect the design of the MTV. Finally, construction and maintenance techniques must be chosen so as to reduce risks, cost, and complexity in overall vehicle operations. The overall design philosophy adopted is to use conservative estimates when dealing with projections of future technology.

The MTV is 110 m long and has an initial mass of 536 metric tons in Earth orbit. Propulsion is provided by two dual-mode 75,000-lb-thrust nuclear thermal rockets (NTRs) that supply 15 kW of electric power to the vehicle during nonthrusting operations. In the unmanned configuration, the vehicle would carry two 50-ton-capacity cargo landers. In the manned configuration, the MTV carries a habitation module with five crewmembers plus a lander. On a manned mission, the vehicle would return the habitation module and crew to Earth orbit, with the lander remaining at Mars. Typical mission length will be less than two years and the vehicle should be reusable for four or five missions. The projected vehicle lifetime is about 15 years, including layovers at Earth and at Mars.

Assumptions are that the MTV will be constructed in Earth orbit, relying on Space Station *Freedom* and large Orbital Transfer Vehicles (OTVs); nuclear propulsion will be politically feasible from a Nuclear Safe Orbit at about 800 km altitude; low-boiloff, advanced liquid hydrogen tanks will be available; landing sites will be selected using unmanned precursor missions; four major propulsive burns are made during the mission (trans-Mars injection, a braking maneuver at Mars, trans-Earth injection, and a final braking maneuver at Earth); a heliocentric near-Hohmann Earth-Mars transfer is used; and the final orbit is 900 km above the surface of Mars. The orbits of the planets are assumed to be circular and coplanar. The required velocity impulses are found using a patched conic approximation. Using these assumptions, the velocity impulse required for Earth departure is 3.49 km/sec and the velocity impulse at Mars arrival is 2.04 km/sec. The fuel budgets are increased by 10% to account for approximation inaccuracies and midcourse corrections. Under these assumptions, the one-way transfer time is about 260 days.

The spacecraft rotates slowly at about 0.5 rpm to provide uniform solar thermal loading to the vehicle exterior. The nuclear reactors each generate approximately 1556 MW of thermal power during propulsive burns. This heat is transferred to the hydrogen propellant and is rejected when the hydrogen exits the nozzle. This method of heat rejection is also used during the reactor cool-down period. When operating in electrical power generation mode, a reactor will produce about 1 MW of thermal power. Radiators for the power generation system are located on the surface of the power module and on small fins attached to the surface. The masses of the thermal control systems are included in the mass estimates for the propulsion subsystem and the power subsystem.

The vehicle configuration chosen has a single truss surrounding the central tank. The primary structure is an axial truss of square cross-section. The truss is sized to surround a central fuel tank (7.5-m-diameter). Ten truss bays are used to sufficiently distance the radiation-sensitive crew and payload from the NTRs. There are five reusable titanium honeycomb fuel tanks, each 7.5 m in diameter, and 23 m long. Combined, they hold 365 tons of liquid hydrogen (LH_2). The central tank is sized to use the LH_2 to shield the habitation module and payload from the NTRs.

COMPREHENSIVE ORBITAl DEBRIS MANAGEMENT PROGRAM UNDERGRADUATE, SPRING 1990

Since the launch of Sputnik I in 1957, humans have placed over 19,500 objects into various orbits around the Earth. Of these objects, many unwanted ones have been removed through reentry, but over 7100 unnecessary items large enough for routine tracking remain in orbit. In addition, the North American Defense Command estimates that there are 40,000 to 55,000 residual orbiting objects that are too small to be tracked.

These remnants, commonly known as space debris, pose serious risks to space operations. A collision with space debris could result in the death of crew and/or destruction of property. In addition, there is also the possibility of a cascade (Kessler) effect. Originally predicted by Donald J. Kessler, space debris expert at NASA, the cascade effect theory predicts that debris could become self-generating in the near future. Kessler asserts that even if no new objects are placed in orbit, fragmentation from the collisions between existing objects will not only increase the amount of debris, but will result in more collisions causing an exponential growth of space debris.

Due to the dangers of space debris, viable long-term solutions must be developed and implemented before the situation becomes uncontrollable. Because of the cascade effect, solutions such as satellite shielding or debris avoidance systems provide no long-term help. Long-term solutions involving space debris removal are being studied in order to address the cascade effect and reduce the threat to current and future space endeavors.

The proposed debris management plan includes debris removal systems and preventive techniques and policies. The debris removal is directed at improving the current debris environment. Because of the variance in sizes of debris, a single system cannot reasonably remove all kinds of debris. No

effective system is currently available to remove the debris smaller than 10 cm in diameter. However, an active removal system, which deliberately retrieves targeted debris from known orbits, was determined to be effective in the disposal of the larger debris that can be tracked directly from Earth.

A roving debris-removal vehicle, based on the OMV, has been designed to rendezvous with large debris pieces, attaching deorbit propulsion modules. The roving debris-removal vehicle has two arms and "glues" the deorbit propulsion system to the debris pieces. Telerobotic control is used on the roving vehicle. The vehicle is periodically resupplied using a launch-on-demand refueling vehicle. The refueling vehicle deorbits itself after transferring the supplies and fuel to the roving debris-removal vehicle.

The second part of debris management is its prevention. This prevention program is intended to protect the orbital environment from future abuses. This portion of the plan involves various methods and rules for future prevention of debris. The preventive techniques are protective methods that can be used in future design of payloads. In order to encourage launching states to employ these preventive measures, several international treaties have also been proposed.

MICROGRAVITY FREE-FLYERS FOR SPACE STATION UNDERGRADUATE, SPRING 1990

The goal of this project is to design a spacecraft that will be used with Space Station *Freedom* to provide the best possible environment for microgravity experiments. Astronauts, pumps, and other vibration-causing entities onboard *Freedom* cause this environment to be degraded substantially. A free-flyer will be designed to overcome these disturbances by being removed from *Freedom* while microgravity experiments are running. The mass of the experiments will be up to 1000 kg, with experiment lifetimes up to 2 years. The free-flyer will automatically deploy, maintain stability, reboost when necessary, and return to *Freedom* for changing experiments.

A typical mission profile will consist of placing experiments onboard, performing a check-out of the systems, deploying the free-flyer, controlling the attitude and orbit, sending experimental data to *Freedom*, reboosting when necessary, returning to *Freedom*, docking, and changing experiments. Each aspect of the mission presents problems. The level of human interaction—that is, how much of the astronauts' time will be required—will have to be determined by the free-flyer. Experiments will have to be fitted to each free-flyer mission. Power requirements, communication requirements, microgravity tolerances, and duration requirements must be considered for each experiment onboard the free-flyer. Compatible experiments will then be fitted together. The free-flyer should be stabilized with minimum acceleration and vibration.

The free-flyer is designed to be placed in orbit by the space shuttle and to fly up to five experiment modules. The core vehicle contains one or more power modules, a variable capability propulsion module, a thermal management system, and an attitude control system. Any module can be replaced using the Space Station mobile manipulator arm.

ALL-TEXAS EDUCATIONAL SATELLITE SYSTEM UNDERGRADUATE, SPRING 1990

In an effort to unite educational resources throughout the state of Texas, the 1989 Texas Senate passed Senate Conference Resolution No. 23. This resolution directs the Automated Information and Telecommunications Council to study the feasibility of a state-sponsored educational satellite project. The objective is to design a satellite communications system (TEXSTAR) that will enhance the educational productivity in Texas. Such a system will enhance education at all levels throughout the state. The design team has designed TEXSTAR, an educational satellite communications system that will be considered a means of equalizing the distribution of educational resources throughout the state. TEXSTAR will be capable of broadcasting live lectures and documentaries, in addition to transmitting data from a centralized receiving-transmitting station. Included in the design of TEXSTAR are system and subsystem design for the satellite and design of ground stations. The launch vehicle used will be the Texas-built Conestoga 421-48. The TEXSTAR system incorporates a cluster of three small satellites in slightly inclined geosynchronous orbits. Because of the configuration and spacing of these satellites, the system will be accessed from ground stations as if it were one large, geostationary satellite.

To fulfill all service objectives, TEXSTAR must be able to relay 20 video signals simultaneously, providing uninterrupted coverage to the entire state 24 hours per day. Transponder number and size, however, must be weighed against the mass and cost of the satellite. This effort is designed to benefit not only the Texas educational system, but also the Texas economy. Therefore, satellite components and launch vehicles designed and built in Texas will be used as much as possible. The success of the TEXSTAR project will provide better services, create jobs, and attract national attention to this innovative solution to our educational dilemma.

LUNAR CORING LANDER SEARCHING FOR WATER AT THE LUNAR POLES UNDERGRADUATE, SPRING 1990

As a new era in manned space exploration of the solar system begins, NASA is turning its sight back to the Moon. Plans to build a lunar base are presently being studied. One of the most important considerations is qualifying and quantifying the presence of water on the Moon. The existence of water on the Moon implies that future lunar settlements may be able to use this resource to produce things such as drinking water and rocket fuel. Because of the very high cost of transporting these materials, *in-situ* production could save billions of dollars in operating costs of the lunar base.

Scientists have suggested that the polar regions of the Moon may contain some amounts of water ice in the regolith. This report suggests six possible mission scenarios that would allow lunar polar soil samples to be collected for analysis. The options presented are a remote sensing satellite; two unmanned robotic lunar coring missions (one is a sample return and one is a data return only); two combined manned and robotic polar coring missions; and one fully manned core

retrieval mission. Each mission has its own advantages and all are considered to be viable with little or no required advancement of the present state of technology.

One of the combined manned and robotic missions has been singled out for detailed analysis. This project proposes sending at least three unmanned robotic landers to the lunar pole to take core samples as deep as 15 m. Upon successful completion of the coring operations, a manned mission would be sent to retrieve the samples and perform extensive experiments in the polar region. The lander subsystems are descent propulsion, automatic landing site selection system, self-leveling landing gear, power, thermal management, drilling and core handling, sample module ascent propulsion, sample return vehicle guidance, sample landing propulsion, and sample package landing gear.

ATLAS AIRCRAFT-BUSHWHACKER PROJECT LOW-INTENSITY CONFLICT AIRCRAFT (LICA) UNDERGRADUATE, SPRING 1990

During the 1980s, the transition from emphasis on full-scale battles to localized low-intensity conflicts created a demand for a low-cost aircraft designed for close-air support against a lightly armed opposition. The Bushwhacker project focused on developing an aircraft that falls between the capability of a counterinsurgency aircraft such as the North American OV-10 developed in the 1960s and the present battlefield tank killer, the Fairchild A-10 developed in the 1970s. Its primary task will be forward air control, which consists of a defined loiter time combined with a series of attack runs to deliver rockets, machine-gun fire, and other antipersonnel ordnances. The low-intensity conflict aircraft (LICA) will be marketed for the U.S. Armed Forces and U.S. allies in the Central American region. The project trade studies are directed toward developing a maneuverable and agile aircraft whose cost does not outweigh its military worth.

The LICA is a straight-wing, twin-turboprop-powered aircraft with a maximum takeoff weight of 16,650 lb, a span of 46.6 ft, a length of 43 ft, and a wing area of 333 sq ft. It carries a payload of 1620 lb, has a maximum attack speed of 325 kt and a stall speed of 132 kt. The sea-level rate of climb is 3500 ft/min. Its takeoff distance is 1000 ft and its landing distance is 700 ft.

THE "GATEKEEPER" MULTIMISSION ANTI-DRUG AIRCRAFT UNDERGRADUATE, SPRING 1990

The flow of illegal narcotics has become an uncontrollable problem. Current drug interdiction methods are failing to curb large amounts of narcotics entering the U.S. onboard light aircraft. Drug-laden aircraft regularly elude radar and evade capture to deliver drugs. U.S. Customs relies on multiple aircraft to perform drug interdiction. Presently, Customs uses radar-equipped E-2C Hawkeyes to search for smugglers. The E-2C guides a Cessna Citation II to a potential target for identification and possible pursuit. If a drug drop is observed, a HU-60 Blackhawk helicopter is directed to apprehend smugglers on the ground.

The Gatekeeper will be a new drug-interdiction aircraft combining the drug-interdiction capabilities of the Citation II and the Blackhawk. Gatekeeper will be designed to intercept a wide variety of adversary aircraft. The DC-3, Cessna 310, and the Cessna 172 (all used to smuggle drugs) will be used to set Gatekeeper performance requirements.

Gatekeeper will have (1) sufficient payload to carry advanced radar for tracking illegal drug aircraft, (2) long endurance to allow sustained surveillance, and (3) a flight envelope wider than the composite envelope of the three competitor aircraft mentioned above. This will enable Gatekeeper to apprehend drug smugglers and should serve as a potent deterrent to the import of illegal drugs in the U.S. The Gatekeeper design features a span of 62 ft, a length of 42 ft, a cruise speed of 120 mph, with a maximum speed of 0.78 Mach. Its design cruise altitude is 7000 ft and its range is 1970 n.m. The Gatekeeper weighs 23,000 lb at takeoff, and carries 7300 lb of fuel and a payload of 2500 lb. It is powered by two 3300-hp turboprops with counterrotating propellers. It has an aspect ratio of 9 and a wing area of 429 sq ft. Specific fuel consumption is 1.36 lb/hr/lb at cruise.

THE PEREGRINE I, A FUTURISTIC COMPETITION SAILPLANE UNDERGRADUATE, SPRING 1990

In 2050, technological advancements in fields including metallurgy and aircraft design will allow new and innovative ideas to flourish in the public and private arenas. Soaring will replace yachting as the ultimate in international competition, spurring American industry to take the reins in an effort to gain superiority in the highly competitive sport. The goal of this project is to extrapolate the results of current research and use them to conceptually design the Peregrine I, a futuristic sailplane that will lead the United States to preeminence in international competitive soaring. Efforts are made to incorporate the vertical and horizontal tail configurations into the fuselage and wings. To soar competitively using this unconventional no-tail design, the sailplane will employ miniature onboard flight computers. Enormous strides in the study of engineering materials will allow the use of composites to reduce aircraft weight. Additionally, boundary layer control mechanisms and advanced airfoil and wing designs will be considered for the sailplane design. The availability of advanced technologies is being anticipated to conceptually design a futuristic sailplane that will bring the United States to dominance in international soaring competition.

THE "BALLISTICO"—A PLATFORM FOR MICROGRAVITY EXPERIMENTS UNDERGRADUATE, SPRING 1990

The objective of this study is to provide an alternative aircraft to the NASA KC-135 aircraft presently used to conduct parabolic microgravity flights. The purpose of this aircraft is to provide a limited microgravity environment for research applications such as biomedical and human-adaptation studies, materials processing, fluid physics, life sciences, and spaceflight hardware testing. The mission performed by the KC-135

consists of 40 parabolas with a microgravity time of 25 sec/parabola. The Ballistico's mission requirements are to conduct 72 parabolic maneuvers with a microgravity time of 28 sec/parabola. The aircraft is similar in design to the KC-135 with the capacity for 20-25 passengers and 20,000 lb of research equipment.

The Ballistico aircraft is a 230,000-lb (takeoff weight), four-engine aircraft with four Rolls Royce RB211-535C engines at 37,000 lb thrust each at sea level. The aircraft carries a 24,900-lb payload and has a ceiling of 37,000 ft. The wing area is 1716 sq ft, the span is 115 ft, and the length is 156 ft. The cruise speed is Mach 0.82 at 25,000 ft.